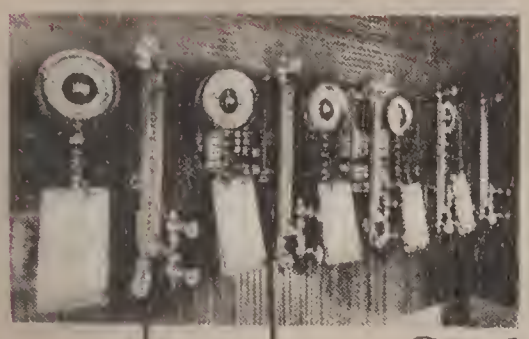
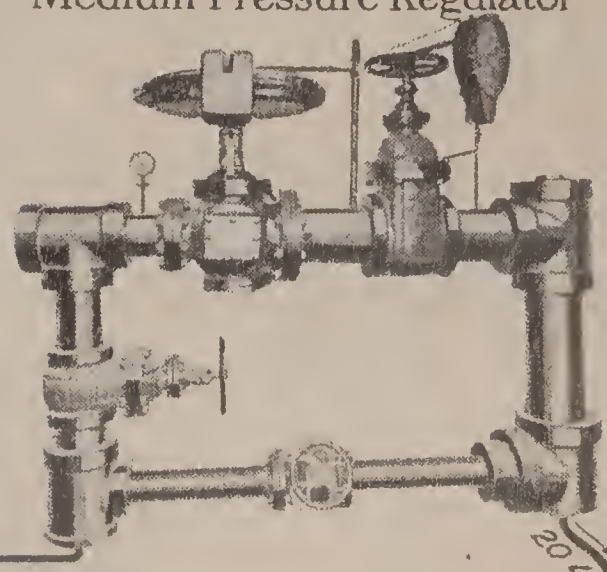
ITS OF
PPLY COMPANY



Gas Measuring
Station at Gates of Town

Medium Pressure Regulator



100 LBS.

Gas Transmission Line

Medium Pressure Gas Line in Town Distributing System 8 oz.

NATURAL GAS SERVICE

BY

SAMUEL S. WYER, M. E.

CONSULTING ENGINEER, COLUMBUS, OHIO

MEMBER:

AMERICAN SOCIETY MECHANICAL ENGINEERS.
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AMERICAN ACADEMY POLITICAL AND SOCIAL SCIENCE.

AUTHOR:

PRODUCER GAS AND GAS PRODUCERS.
REGULATION, VALUATION AND DEPRECIATION OF PUBLIC UTILITIES.

"We may live without friends:
We may live without books:
But civilized man cannot
Live without cooks."

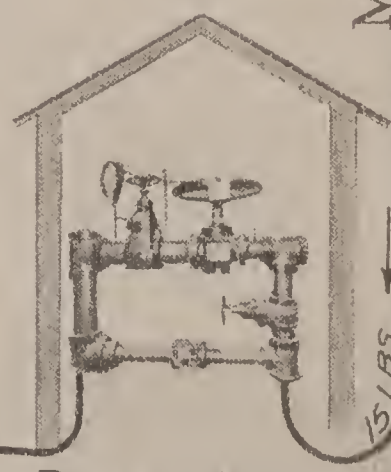
4 OZ.

Service Line

Gas Meter

Service Cock and Box

Low Pressure Gas Line



5 LBS.

Low Pressure Regulator

CHEAPNESS OF FIFTY CENT NATURAL GAS SERVICE.

Fifty-cent natural gas service used for lighting is only:

60% of cost of electricity at 5c per K. W. in Tungsten lamp;
50% " " " artificial gas at $1 per "M" in mantle;
50% " " " gasoline at 18c per gal.;
23% " " " electricity at 5c per K. W. in carbon lamp;
20% " " " coal oil at 12c per gal.;
20% " " " acetylene with carbide at 4c per lb.;
19% " " " artifical gas at $1 per "M" in flat flame burner.

Fifty-cent natural gas service used for cooking and heating is only:

50% of cost of coal oil at 12c per gal.;
32% " " " gasoline at 18c per gal.;
32% " " " artificial gas at $1 per "M";
9% " " " denatured alcohol at 40c per gal.;
3½% " " " electricity at 5c per K. W.

TWO OF THE ILLUSTRATIONS AND SEVERAL SECTIONS OF THE TEXT USED HEREIN ARE ADAPTED FROM, AND USED WITH THE PERMISSION OF THE SEARS & SIMPSON CO., PUBLISHERS OF WYER'S REGULATION VALUATION AND DEPRECIATION OF PUBLIC UTILITIES.

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COLUMBUS, OHIO.
JUNE, 1913.

$1.50
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TN820
W84

Natural Gas Service.

What Is Natural Gas? This is a highly combustible gas made by a secret process of nature; is the most perfect fuel known, and has never been equaled by any man-made product. It is not a chemical compound, as popularly supposed, but a mechanical mixture of several gases, the number and exact proportions—of the various constituents—varying somewhat for the different localities and during the working lives of individual wells.

What Natural Gas Does for a City. The smoke nuisance in the average city is not caused primarily by the factory, but by the total smoke from the homes. Smoke prevention appliances cannot be used in the home as they can in the factory, and the solution of the smoke problem depends upon the burning of gas instead of solid fuels in homes, as so well stated by Mayor Baker in the following:

> "While we have in a great many ways endeavored to abate the smoke nuisance by ordinary means, yet I realize that no one thing has contributed so enormously to our success in that regard as natural gas at a figure that competes fairly easy with many of the uses for which soft coal was previously utilized. I know that so far as the city of Cleveland is concerned, it is very doubtful whether anything has ever happened in this city,—any one thing—which did more for its prosperity, did more for its beauty, did more for the convenience, the comfort, the happiness, and perhaps the health of the people who live here, than the introduction of natural gas." (1)

Gas Meters.

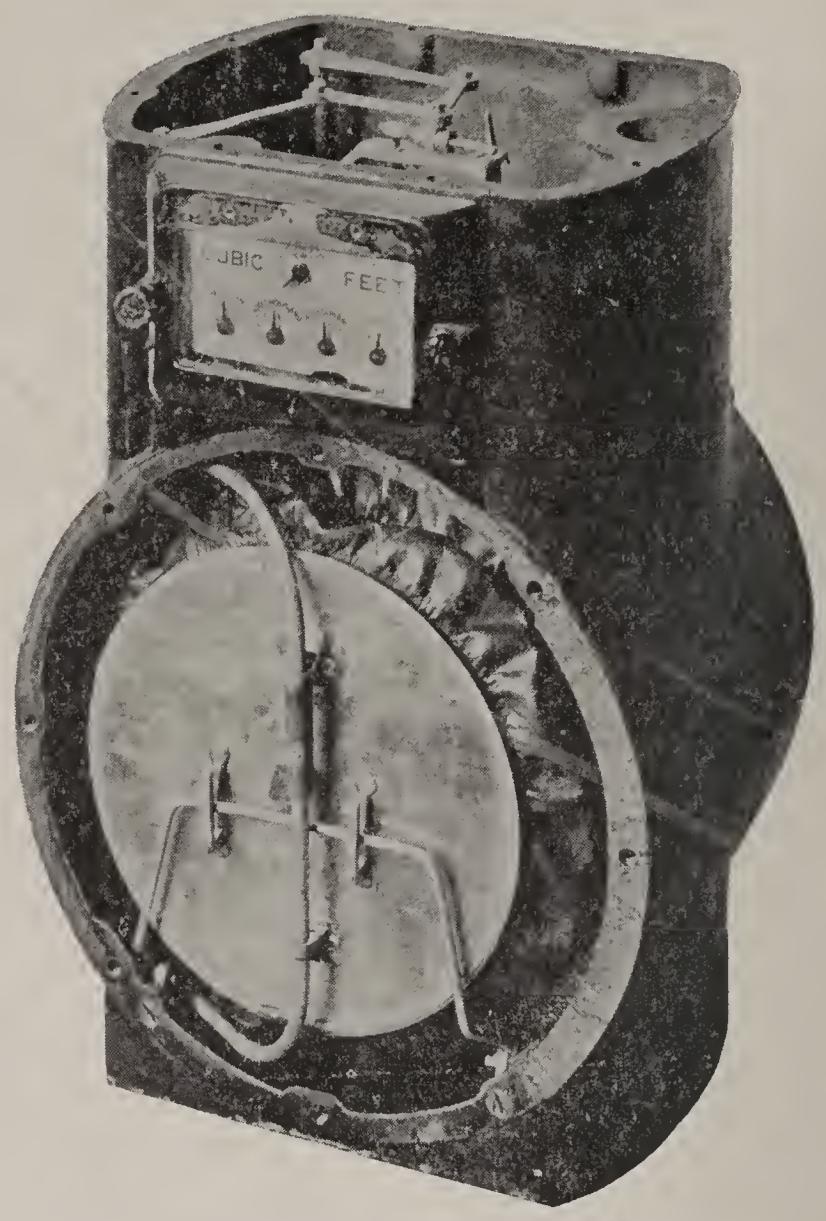
> "The public has a marked feeling of distrust for the gas meter. To the average man it is simply a machine for making large gas bills. The fact, however, is that the gas meter is merely a measuring device that stands between the gas company and the gas consumer, registering more or less accurately the amount of gas that passes through it. Furthermore, like all man-made appliances, the gas meter will get out of adjustment, and when out of adjustment it will register too fast or too slow, the former to the detriment of the consumer, and the latter to the detriment of the gas company. It is impossible to keep a gas meter in continuous actual working condition that will be absolutely accurate, and the consensus of expert opinion allows a range of from two to three per cent either fast or slow. All meters coming within this limitation are regarded as practically correct." (2)

(1) Hon. Newton D. Baker, Mayor of Cleveland, Ohio, in address before Natural Gas Association of America, Cleveland, Ohio, May 20, 1913.

(2) Report on Natural Gas Service Rendered the City of Columbus, Ohio. By Consulting Engineers E. A. Hitchcock and Samuel S. Wyer, p. 28.

13-1203

Domestic Gas Meter Construction. An ordinary gas meter with covers removed is shown at the right. This measures the gas passing through it by alternately filling and discharging flexible pockets, or diaphragms, that work on the same principle as the old-fashioned hand-bellows used about fireplaces. One of these leather diaphragms is shown extended at the front of the illustration. Each leather diaphragm receives a definite quantity of gas and then expels it, having the same stroke every time. By means of the clock work shown at the top, each stroke of the diaphragm is registered in terms of cubic feet on the dial, the diaphragms receiving their power from the pressure of the gas on the intake side of the meter.



Internal Construction of Domestic Gas Meter

Gas Meter Facts. The following facts regarding gas meters should be borne in mind by gas users:

1. "Gas meters have no power within themselves to register. The only way they can be made to register is by the passage of gas through the meter. The gas company has absolutely nothing to do with the operation, nor can it in any way control the registration of the meter. However, many times gas meters register when gas is not being **used,** due to leakage in house fixtures.

2. "The gas consumption will not be increased by the use of a large meter."

3. "The gas consumption will not be decreased by the use of a small meter. In fact, if the meter is too small the gas service will be unsatisfactory."

4. "Gas bills are **not** made out regardless of gas consumption. While it is possible for the meter reader to make an error for one month, this will be automatically rectified in the reading of the following month."

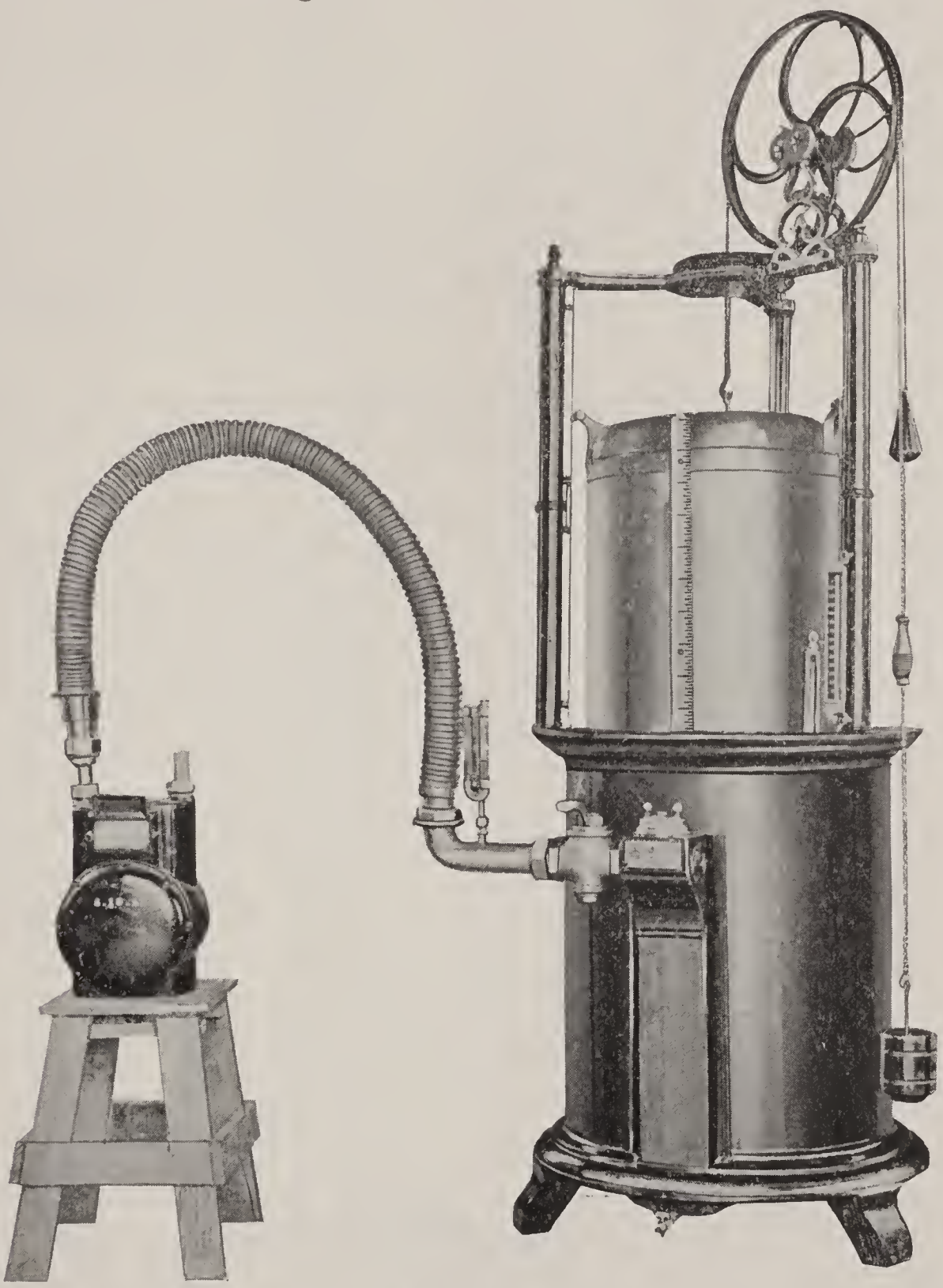
5. "High gas pressure does not increase the rate of registration of meter."

6. "Low gas pressure does not decrease the rate of registration of the gas meter."

7. "It is impossible for a gas meter to register twice. When the gas has passed through the meter it cannot pass through the second time."

8. "Meters do not always register fast. There are times when they register slow, and this is to the detriment of the gas company." (1)

Testing Gas Meters. This is done by simply passing a certain number of cubic feet of air or gas through the meter from a gas prover, as shown below, the prover being first tested and sealed by the State Sealer of Weights and Measures.



Gas Meter Prover

(1) Report on Natural Gas Service Rendered the City of Columbus, Ohio. By Consulting Engineers E. A. Hitchcock and Samuel S. Wyer, p. 29.

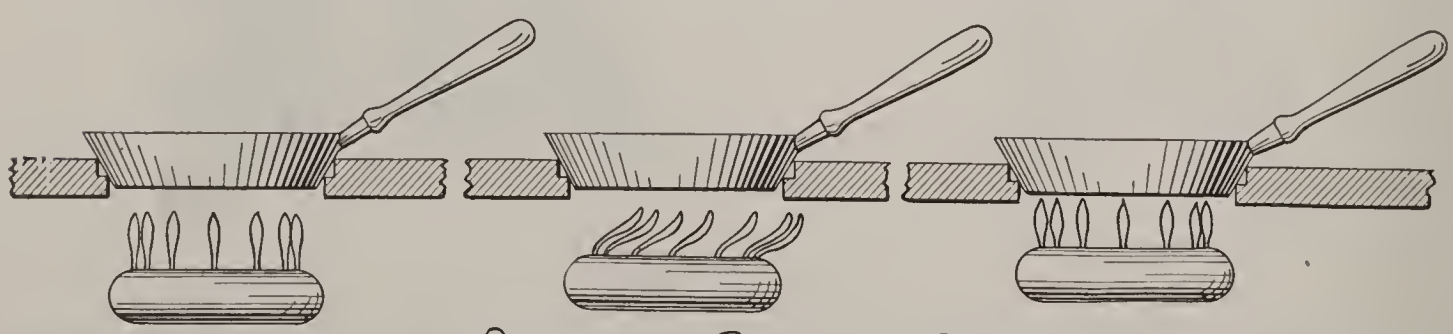
Average Monthly Gas Bills. The following tabulation, based on natural gas at 30c net per 1,000 cu. ft. emphasizes a peculiar and almost universal mental attitude of natural gas consumers, namely, that the only bills that are remembered are the few large ones, the mean average for the year being entirely forgotten:

July	$ .30	
August	.60	
September	1.20	
October	1.80	
November	2.10	
December	4.20	
January	8.40	These are the only bills the consumer remembers.
February	9.00	
March	3.00	
April	1.50	
May	.60	
June	.30	
Total for year	$33.00	
Average for month	2.75	

The relatively small part that natural gas plays in the average family budget is shown on next page. This classification is based on large number of studies made by Richards of the Massachusetts Institute of Technology, with the natural gas features detailed by the author.

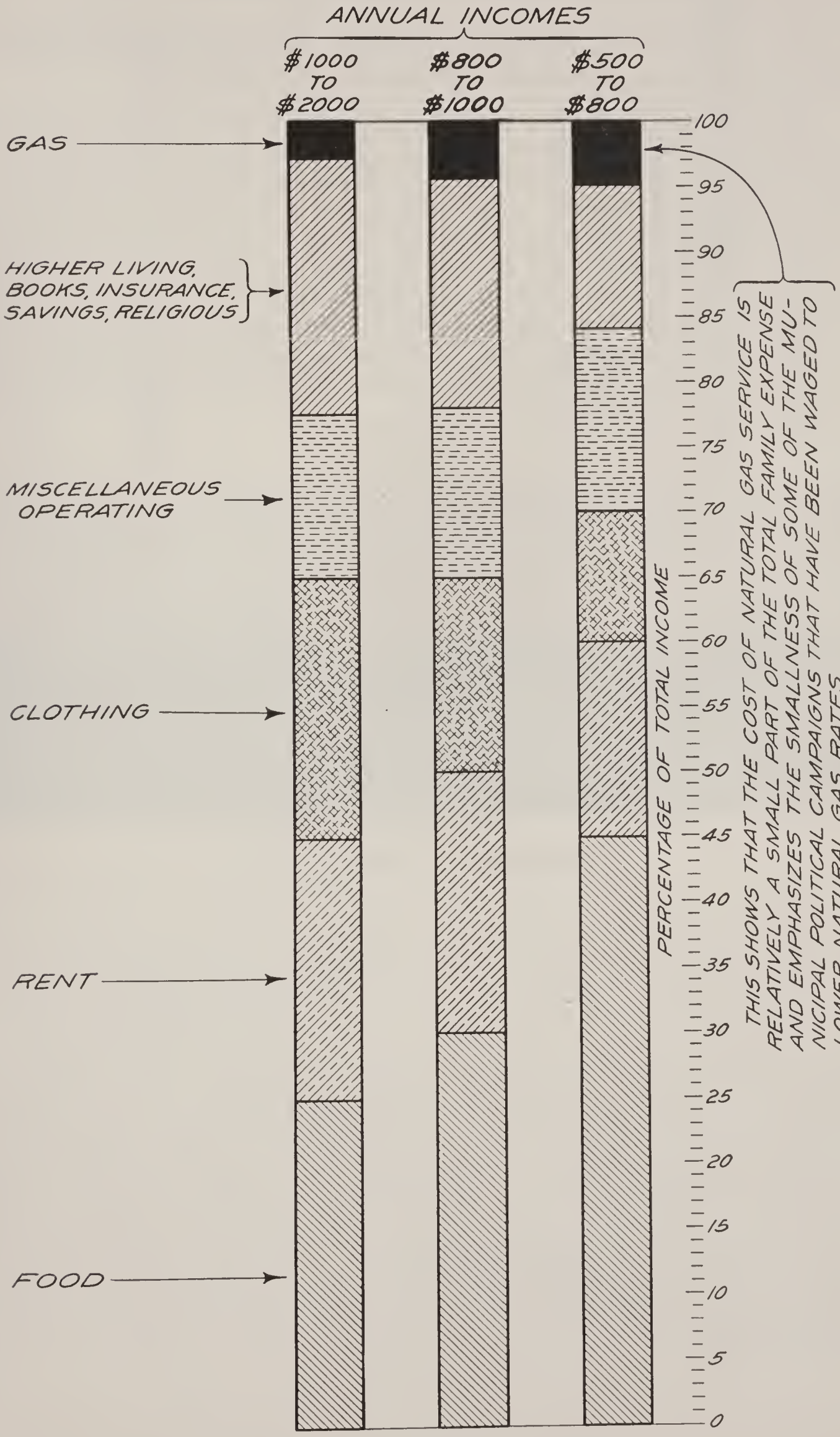
Consumer Is Responsible for Economic Use of Gas. The consumer's use of gas has an important bearing on the efficiency of the results that may be obtained, as illustrated on this page, which shows an ordinary skillet over a gas range fire. Few appreciate that, in cooking service, for instance, effective results cannot be obtained unless the tip of the flame strikes the vessel that is being heated. At 2, on account of an abnormally strong draft, the flame is deflected; at 1 the burner is too low, while at 3 the flame conditions are such that effective results can be obtained. This has a specially marked effect on low pressure conditions which will result in short flames. Under such conditions, even though a flame may be short, if it is so placed as to properly strike against the cooking vessel, effective results may be obtained. It has been demonstrated that under low pressure conditions potatoes that could not be started to fry in 30 minutes under conditions indicated by 1 and 2, with the same pressure and same gas consumption, could be burned to a crisp inside of five minutes if the conditions indicated by 3 prevailed.

USE OF NATURAL GAS FOR COOKING



BURNER TOO LOW 1 — DRAFT TOO STRONG 2 — CORRECT AND EFFECTIVE 3

PERCENTAGE OF DIFFERENT FAMILY ANNUAL INCOMES SPENT FOR NATURAL GAS SERVICE



When mantle burners are opened so as to admit more gas than is necessary, the familiar "hissing" or blowing sound is produced. This has, first, a tendency to break the mantle and chimney; second, waste the gas; and third, lowers the candle power of the lamp.

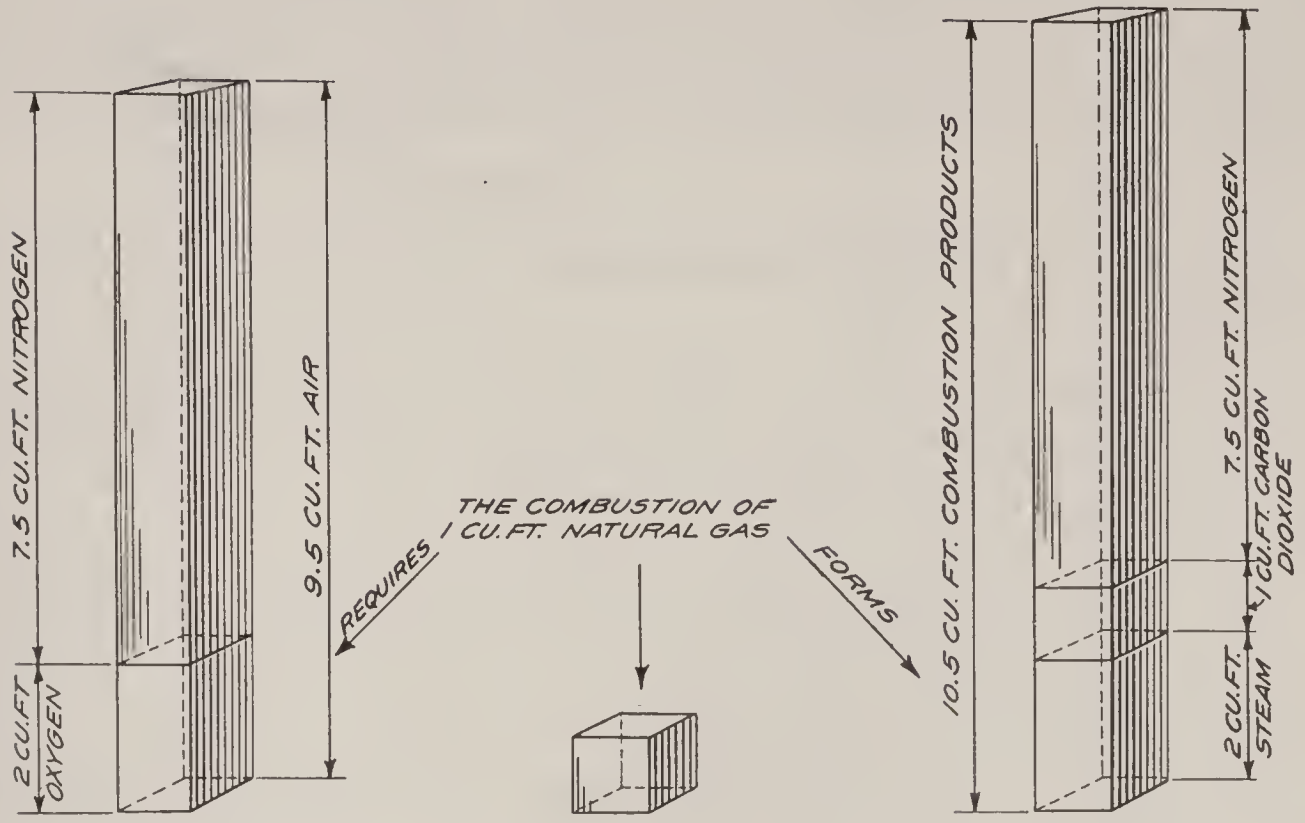
The majority of natural gas consumers do not appreciate that gas burners need care and attention, and that periodic cleaning is absolutely essential if satisfactory results are to be obtained.

The data in the first and second columns from the right on page 9 show the marked difference in results that may be obtained by using natural gas in an ordinary coal furnace as against an especially built natural gas furnace. The author has made tests under actual routine working conditions which show that an auxiliary natural gas furnace, built especially for natural gas, may be installed alongside of an ordinary coal furnace and the heated air from the auxiliary furnace turned into the shell of the coal furnace without disturbing the hot air pipes of the coal furnace and at the same time secure an efficiency of at least twice that which can be secured from burning natural gas in an ordinary coal furnace.

Gas Compressing Station at Sugar Grove, Ohio

Effect of Gas Fumes on Air. The average gas user does not appreciate the large volume of air necessary and large volume of combustion products given off in the burning of natural gas as shown on next page, and the resulting necessity of proper ventilation if satisfactory results are to be expected. Carbon dioxide and steam are always formed when gas is burned, the relative amount of each being dependent on the chemical composition of the particular gas. If safe and hygienic conditions are to be maintained in rooms heated by gas fires, chimney provision must be made for the removal of the combustion products. The so-called odorless, smoke-consuming and chimneyless gas heating appliances are not only frauds, but also a positive menace to health, and ought never be used. The retaining of the combustion products in the room produces a cold and clammy sensation that frequently causes the consumer to erroneously blame the gas service.

COMBUSTION OF NATURAL GAS



High Gas Bills. The cause of real and alleged high gas bills may be as follows:

1. Leakage in house piping.
2. Ineffective application or use of gas by consumer.
3. Dirty gas-using appliances.
4. Improper adjustment of gas mixers.
5. Carelessness in allowing gas fixtures to remain open when gas is not needed.
6. Retaining combustion products in room, thereby producing a cold and clammy atmosphere.
7. Change of dates of meter readings.
8. Meters will always record abnormal amounts of gas used even though consumer may forget such abnormal gas demands by time gas bill is paid.
9. Inadequate pressure.
10. Fast meters.

Gas is Neither Light nor Heat. The gas simply acts as a carrier of heat energy. The consumer's sole object in buying gas service is to get the heat energy that the gas carries. Furthermore, in the burning of gas it is physically, chemically and practically impossible to produce heat without evolving light, or to produce light without producing heat simultaneously.

The introduction of the incandescent mantle, of which the Welsbach is a well-known type, has practically revolutionized gas illuminating methods. In the incandescent mantle, the illumination does not come from the gas, but instead is produced by the incandescence

of the mantle, resulting from the high temperature produced by the combustion of the gas. This mantle has made it possible to secure better illumination from the non-luminous natural gas than was ever possible with any artificial gas, as shown in the third column from the right on p. 9. The data on p. 9 show that natural gas can do everything that artificial gas need do, and several things that artificial gas cannot do.

Natural Gas Service Characteristics. These may be summarized as follows:

1. Public does not appreciate true value of natural gas service as compared with other heating and lighting services or heating and lighting commodities.
2. Public does not appreciate large investment necessary to transmit gas from the gas field to the consumer's premises.
3. Depletion of all gas fields is very rapid.
4. Useful commercial life of plant is limited by commercial life of gas fields.
5. Company has no control whatever over quantity or quality of gas supply, and is entirely at Nature's mercy.
6. Investment hazard is greater than that of any other utility.
7. Fixed charges are larger than for any other utility.
8. Large variation in daily loads—see p. 10.
9. Large variation in seasonal loads—see p. 11.
10. Must make large investment that is used only for a short period each year to take care of the peak load service.
11. Must carry large investment in non-productive leased ground in order to be able to maintain an adequate reserve supply of gas for future use.
12. Underground structures represent major part of investment.
13. Shrinkage in volume of gas, due to leakage in transmitting from gas field to consumer, is enormous.
14. Liability for gas explosions from leaks in plant.
15. Each new consumer requires an additional investment.
16. Most rate schedules have ignored relative worth of natural gas service, as shown on p. 9.

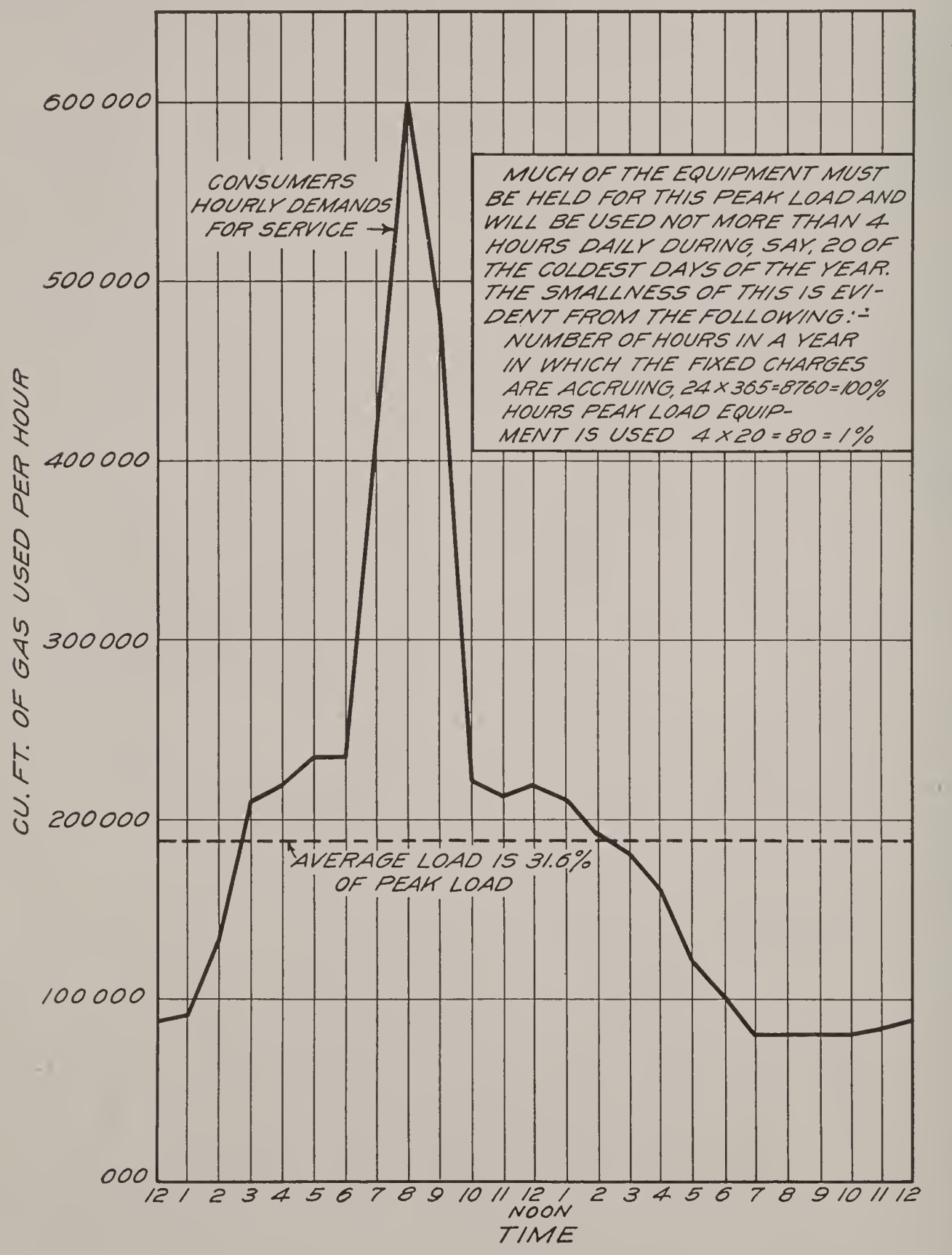
Relative Heat Unit and Candle Power Hour Cost

	NAME	GROSS HEAT UNITS PER UNIT	PRICE PER UNIT	WHAT ONE DOLLAR WILL BUY			
				NUMBER HEAT UNITS	NUMBER CANDLE POWER HOURS SERVICE	HOT AIR FURNACE HEATING SERVICE	
						PERCENTAGE OF HEAT UNITS IN FUEL ACTUALLY UTILIZED BASED ON TESTS	NUMBER HEAT UNITS AVAILABLE IN HEATED AIR
PURCHASED AS A COMMODITY	ANTHRACITE COAL	14000 PER LB.	$10.00 PER TON	2800000		COAL FURNACE 20%	560000
	SEMI-ANTHRACITE COAL	13500 " "	$6.00 " "	4500000			900000
	BITUMINOUS COAL	12500 " "	$4.00 " "	6250000			1250000
	CRUDE OIL	152000 PER GAL	3¢ PER GAL.	5066600			
	KEROSENE	124000 " "	12¢ " "	1033000	OIL LAMP 5350		
	GASOLINE	118000 " "	18¢ " "	655500	GASOLINE LAMP-13000		
	DENATURED ALCOHOL	73000 " "	40¢ " "	182500			
	ACETYLENE	1400 PER CU.FT.	4¢ LB. CARBIDE	140000	ACETYLENE BURNER-5000		
PURCHASED AS A SERVICE	NATURAL GAS	1000 " "	50¢ PER 1000 CU.FT.	2000000	WELSBACH BURNER-26400	GAS BURNER IN COAL FURNACE 30% GAS FURNACE 62%	600000 1240000
	ARTIFICIAL GASES — OIL GAS	640 " "	$1.00 " " "	640000	FLAT FLAME BURNER-5000 WELSBACH BURNER - 13000		
	ARTIFICIAL GASES — RETORT COAL GAS	640 " "	$1.00 " " "	640000	FLAT FLAME BURNER - 5000 WELSBACH BURNER - 13000		
	ARTIFICIAL GASES — GASOLINE GAS	625 " "	$1.00 " " "	625000	FLAT FLAME BURNER - 5000 WELSBACH BURNER - 13000		
	ARTIFICIAL GASES — COKE OVEN GAS	600 " "	$1.00 " " "	600000	FLAT FLAME BURNER-5000 WELSBACH BURNER - 13000		
	ARTIFICIAL GASES — CARBURETED WATER GAS	600 " "	$1.00 " " "	600000	FLAT FLAME BURNER-5000 WELSBACH BURNER-13000		
	ELECTRICITY	3412 PER K.W.	5¢ PER K.W. HR.	68200	CARBON LAMP 6000 TUNGSTEN LAMP 16000		

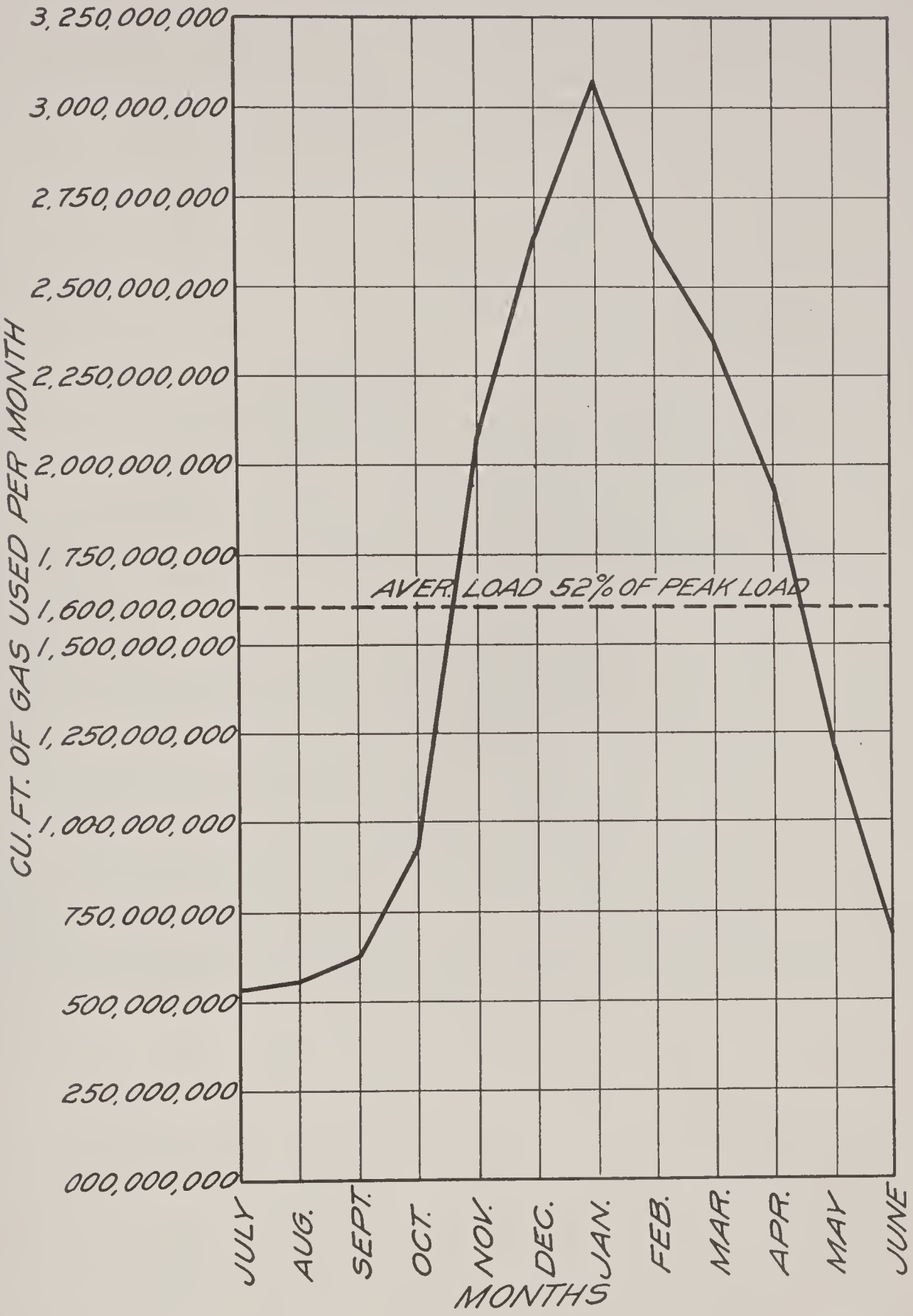
Natural Gas a Service, Not a Commodity. The primary object of a natural gas company is to render a service rather than furnish a commodity. To consider the gas merely as a commodity is fundamentally wrong.

The distinction between rendering a service and manufacturing a commodity is an important one. The commodity may be manufactured at a uniform rate of production and then placed in storage until it can be sold to advantage. A service must be used at the moment it is offered or it will become forever useless. The load data below emphasize the erratic nature of natural gas loads and the many opportunities for rendering services that are never used.

TYPICAL HOURLY NATURAL GAS LOAD IN WINTER


600 000
500 000
400 000
300 000
200 000
100 000
000
CU. FT. OF GAS USED PER HOUR
CONSUMERS HOURLY DEMANDS FOR SERVICE →
MUCH OF THE EQUIPMENT MUST BE HELD FOR THIS PEAK LOAD AND WILL BE USED NOT MORE THAN 4 HOURS DAILY DURING, SAY, 20 OF THE COLDEST DAYS OF THE YEAR. THE SMALLNESS OF THIS IS EVIDENT FROM THE FOLLOWING:-
NUMBER OF HOURS IN A YEAR IN WHICH THE FIXED CHARGES ARE ACCRUING, 24 x 365 = 8760 = 100%
HOURS PEAK LOAD EQUIPMENT IS USED 4 x 20 = 80 = 1%
AVERAGE LOAD IS 31.6% OF PEAK LOAD
12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
NOON
TIME

MONTHLY DOMESTIC LOAD OF NATURAL GAS CO.



Peak Load Service. Abnormal peaks of very short duration are characteristic of all natural gas loads, as shown on p. 10. This necessitates a large investment for equipment that is actually used only a very short period out of each year. Even though the peak load equipment is used for a few hours out of each year, the investment must be made to render the service and adequate returns must be made on the investment.

Peak Loads Increase Cost of Service. An increase of volume of business can decrease the cost of production only when the increment of increase is distributed so as to make possible the more efficient use of existing equipment. When the increment of increase is concentrated so as to require more equipment, as is the case in all peak loads, the cost of production per unit of service is increased. Therefore, the cost of peak load natural gas service is greater than the cost of normal service. A rate schedule, to be equitable to all consumers of natural gas, must make the consumers who need and create the peak load service pay a price that will be commensurate with the extra cost of the service they are receiving.

House heating furnace services not only produce marked peaks each day, but the consumption is limited to relatively a short period out of each year. For this reason house heating furnace service costs more than ordinary gas service.

Distinction Between Luxury and Necessity in Natural Gas Service. To the average family for cooking, hot water boiler heating, lighting and incidental house heating service, natural gas is a necessity, but when used in larger quantities, or for house heating furnace work it becomes a luxury. Furthermore, the peak load characteristics of house heating furnace service makes this service cost more to the natural gas company. An equitable schedule of rates ought, therefore, to provide for a fixed net price per thousand cubic feet for a large enough monthly consumption to permit of the cooking, hot water boiler heating, lighting and incidental house heating service necessary to the average family. If this fixed consumption is exceeded, then the price per thousand cubic feet for such excess consumption ought to be increased so as to make the consumer pay for the higher priced service he is receiving.

Readiness to Serve.—An important characteristic of natural gas is that the service must be available for instantaneous delivery. Each patron, whether he uses much or little of the available service, enjoys the benefit of the ready service always at hand and ready to be used, and if on a meter basis, paid for only when used.

Gas Leakage in Homes. In order to ascertain how much gas is wasted in the premises of the average consumer, some time ago the author made tests at representative houses to determine accurately the amount of gas that passed through the meter when no gas was being used on the premises by the consumer. The rate of leakage was such that it would amount to much more in each home per annum than is ordinarily appreciated.

Laying Gas Lines Across Ohio River

Explosibility of Natural Gas. In natural gas engine work it is important to note that mixtures of natural gas and air are explosive within only a small range. The mixture cannot be exploded if more than 95 per cent, or less than 88 per cent of air is present, the most sensitive mixture being with about 91½ per cent of air.

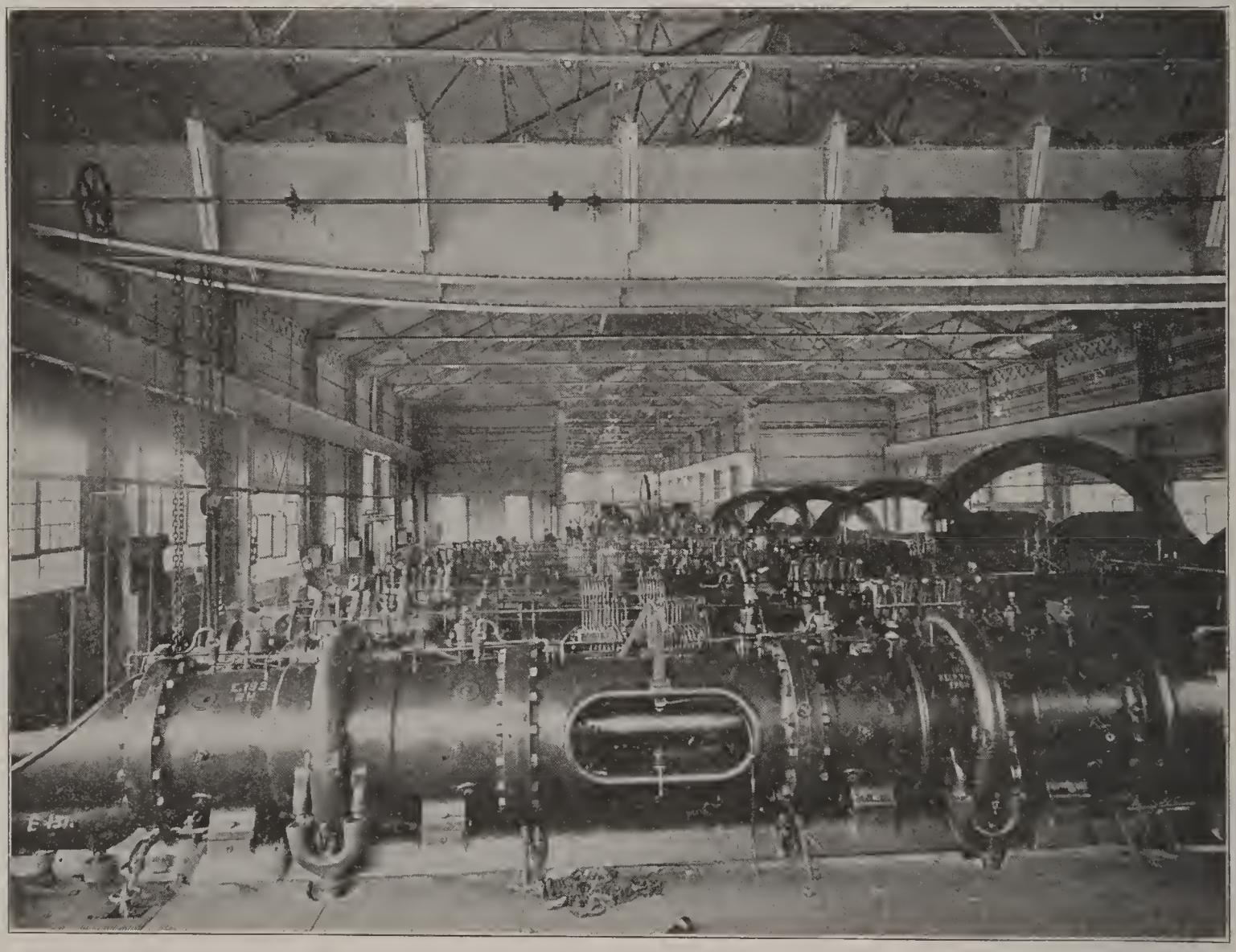
Worth of Natural Gas As a Heating Service. The relative worths of various heating commodities and services are shown in the first and fourth columns from the right on p. 9. The efficiencies given in the second column from the right are based on actual tests under routine operating conditions. These show, first the desirability of using a special natural gas furnace for house heating service, and second, that with such a furnace, $4.00 bituminous coal and 50c

natural gas are equivalents, so far as the cost is concerned, without considering the many advantages of gaseous fuel over soft coal, such as the absence of handling ashes, elimination of operating labor, easier control of fire, and freedom from soot.

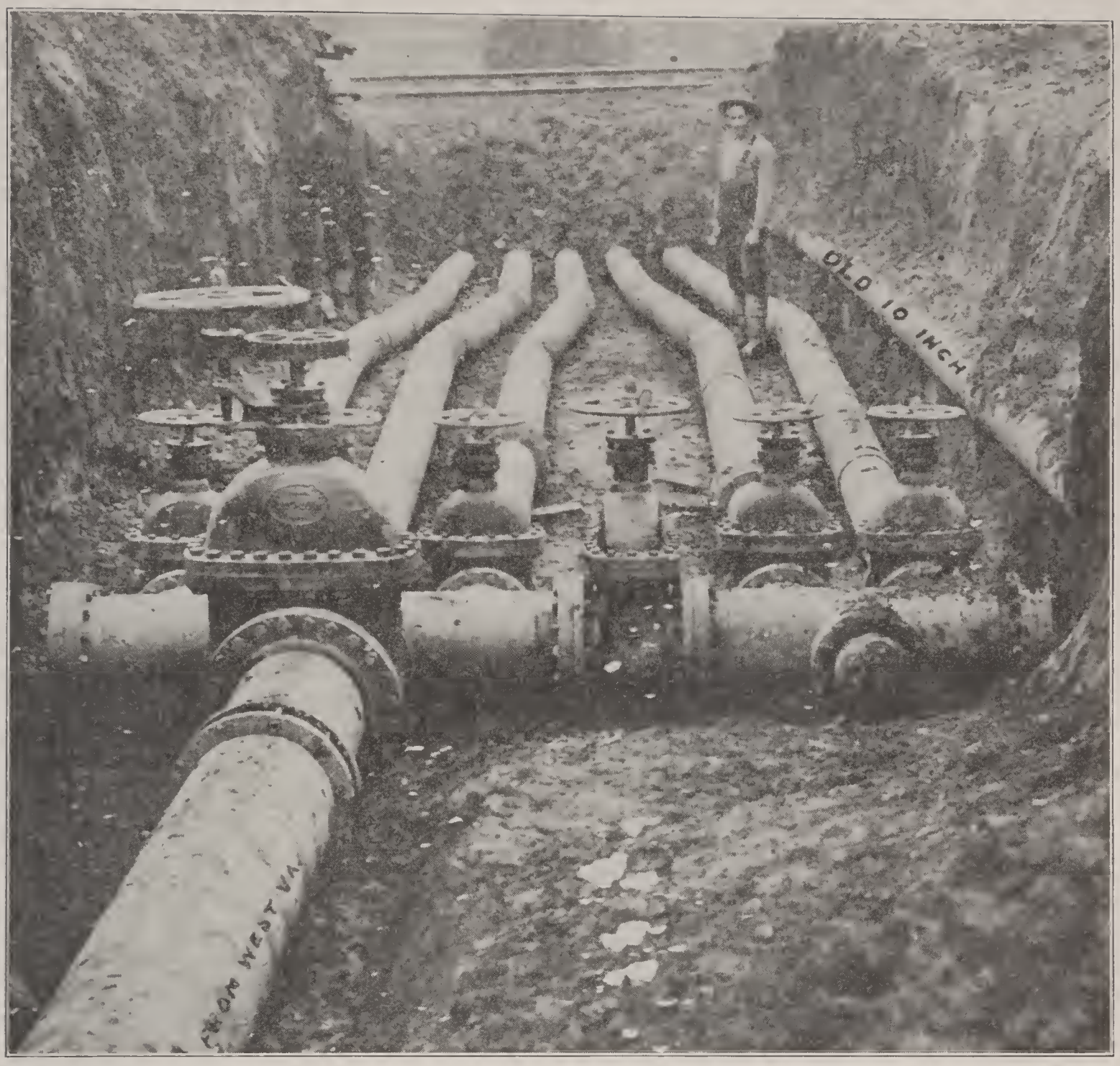
Lack of Appreciation of Natural Gas Service.

1. The average price of artificial gas in the United States is over 85c per thousand cubic feet.
2. Natural gas, on a heating value basis, volume for volume, is worth 50 per cent more than artificial gas.
3. The developed natural gas supplies of this country are capable of serving less than 8 per cent of the inhabitants; hence the undeveloped gas selling territory for this best of all of nature's fuels is almost unlimited.

In the face of the features just mentioned, many state and municipal legislators and utility commissions are attempting to lower natural gas rates and impose other onerous and useless burdens upon natural gas companies. A typical illustration of the inevitable result of this is shown by the red lines on p. 16, which indicate a pipe line that will take gas from West Virginia and Ohio, **through Ohio** to a group of Indiana towns that appreciate the worth of natural gas.



Eight 1200 H. P. Natural Gas Compressors at Homer, Licking County, Ohio



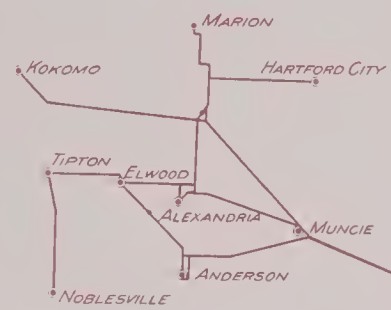
Gas Line Approach to Ohio River Crossing

For structural reasons six 10" lines are used to carry the gas under the river from the one 18" line.

Economy of the Natural Gas Engine. The cost relation of seven typical 50-H. P. plants running 3,000 hours per annum at 2/3 load, is shown in the following:

	Natural Gas Engine	Fuel Oil Engine	Producer Gas Eng. HardCoal	Steam on Gas	Steam on Coal	Gasoline Engine	Electric Motor
Price of Fuel	40c. M.	5c. Gal.	$7 Ton	13c. M.	$2 Ton	16c. Gal.	3c. k. w.
H. P. Hrs. Per Annum	100000	100000	100000	100000	100000	100000	100000
Fuel per Brake H. P. hr.	14 cu. ft.	.12 Gal.	1.125 lb.	80 cu. ft.	10. lb.	.16 Gal.	1 k. w.
Amount of Fuel	1400 M.	12000 Gal.	62.5 T.	8000 M.	500 T.	16000 Gal.	100000 kw
Cost of Fuel	$560	$600	$437	$1,040	$1,000	$2,560	$3,000
6 per cent Interest	105	180	210	120	120	108	48
10 per cent Depreciation	175	300	350	200	200	180	80
Repairs and Incidentals	50	50	100	50	50	50	10
Labor	200	200	300	400	600	200	10
Total Annual Cost	$1090	$1,330	$1,397	$1,810	$1,970	$3,098	$3,148
Power Cost per H. P. Year	$21.80	$26.60	$27.90	$36.20	$39.40	$61.98	$62.96
Licensed Engineer	No	No	No	Yes	Yes	No	No
Boiler Inspection	No	No	No	Yes	Yes	No	No

THE RED INDICATES A GAS TRANSMISSION SYSTEM THAT WILL TAKE GAS FROM OHIO AND WEST VIRGINIA THROUGH OHIO TO A GROUP OF INDIANA TOWNS THAT APPRECIATE THE WORTH OF NATURAL GAS SERVICE.



NATURAL GAS TRANSMISSION LINES IN OHIO

SCALE - MILES
0 5 10 15 20 25 30 35 40

Hazard in Natural Gas Business. "One who invests his money in a business of somewhat hazardous character is very properly held to have the right to a larger return without legislative interference than can be obtained from an investment in a perfectly safe security." (1)

The hazard in the natural gas business is greater than that for any other utility service. The obtaining of natural gas is essentially a mining proposition with, however, more unknown, uncontrollable and uncertain features to cope with than exist in the mining of coal or other minerals. This is because:

A. It is more difficult to determine the outline and volume of a natural gas formation than it is to make a similar determination for coal or other minerals.

B. By reference to p. 19—which is an exact copy of a typical field—it will be seen that the wells of the Blank Natural Gas Co. are surrounded by wells of other companies drawing from the same pools. This makes it impossible for the Blank Natural Gas Co. to hold its supply for future use unless the companies operating the adjacent wells would agree to do likewise. This has a marked effect in decreasing the life of the pool.

C. By reference again to p. 19, it is evident that wasteful methods of other companies will deplete the supply of the Blank Natural Gas Co.

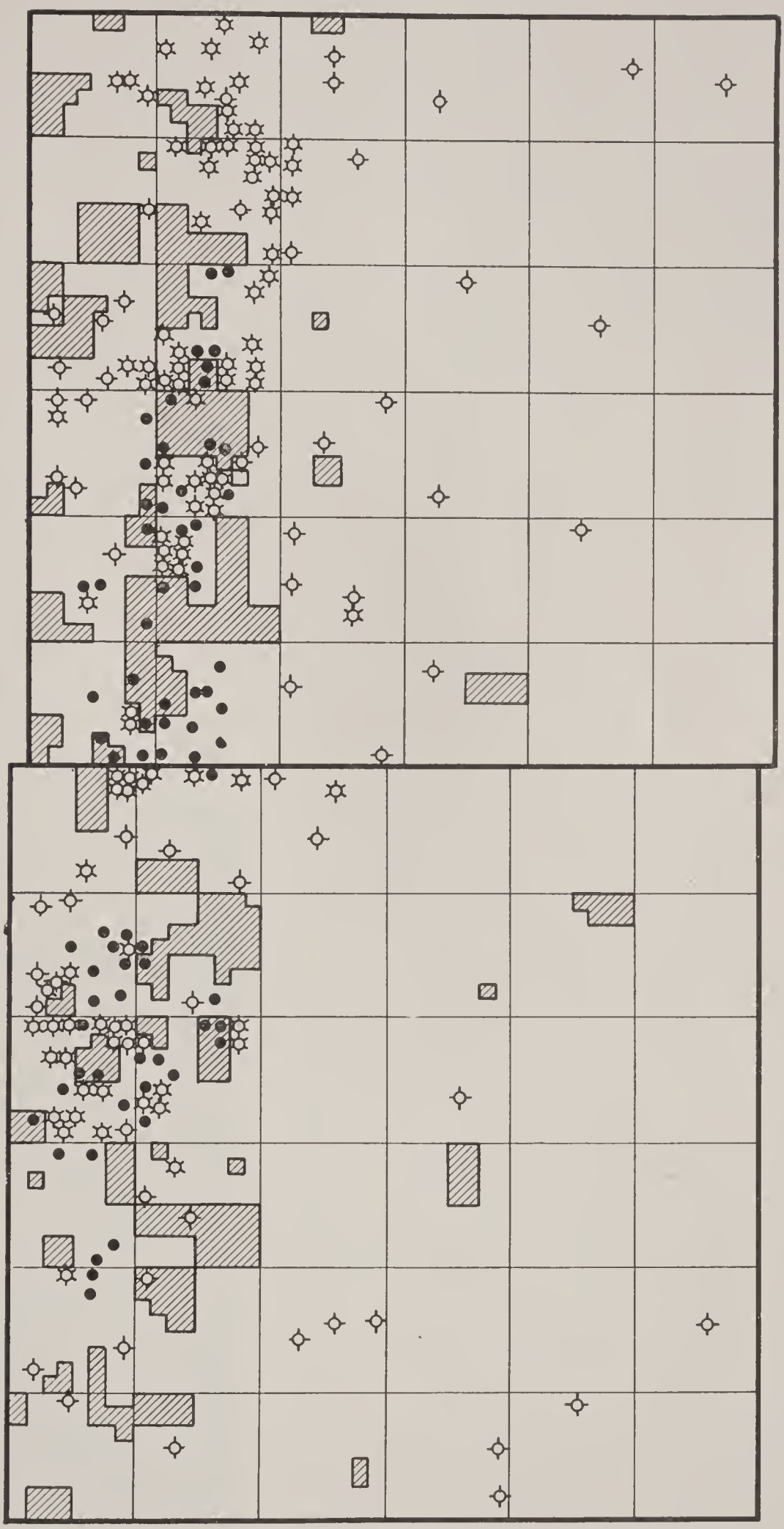
D. Large investment in gas rights, especially in untried acreage that must be held to insure continuous operation. The U. S. Geological Survey statistics show that 390 acres of gas territory is controlled for each producing gas well.

Why Gas Is Compressed. This is merely to expedite transmission—for the same reason that makes it necessary for the farmer to compress cotton, straw or hay for shipment. By increasing the pressure to say 300 lbs. the volume of gas may be contracted to 4.6% of what it would be at atmospheric pressure. Thus the carrying capacity of a gas line at 300 lbs. is 21 times greater than at atmospheric pressure. Without gas compressors the size and number of mains that would be required to bring the gas from the field into the cities would be so large as to make the investment prohibitive.

It is unfortunate that the term "pumping station" has come into universal use in speaking of gas compressing stations, for the reason that the term "pumping" signifies the action of lifting alone, or lifting combined with force. In the case of natural gas transmission the work is one of pure compression, since the gas is delivered to the gas compressors under an initial pressure considerably higher than the atmospheric pressure, on account of the natural rock pressure forcing the gas out from the wells into and through the intake lines to the compressors.

(1) Vol 212, p. 49, U. S. Supreme Court Reports. Wilcox vs. Consolidated Gas Co.

MAP OF GAS FIELD



● WELLS FURNISHING GAS TO BLANK NATURAL GAS CO.

⊕ DRY HOLES

✳ WELLS OF OTHER COMPANIES

▨ LEASES OWNED BY BLANK NATURAL GAS CO.

SCALE 0 1 2 MILES

Creation of Value by Transmission of Gas. The many steps necessary to transmit natural gas from the gas fields to the gas consumer may be seen by holding the outside covers of this pamphlet out flat. This naturally also suggests the large fixed investment necessary to make possible the rendering of such service, and without this the gas in the field is almost valueless. The transmission service is therefore a vital factor in determining the cost of the gas service to the consumer.

How Decrease in Rock Pressure Lowers Compressor Capacity. The rock pressure of wells has a direct bearing on the intake pressure that may be maintained at the gas compressors. The output of a typical compressor operating against a discharge pressure of 300 lbs. gage is as follows, for the respective intake pressures:

Intake pressure above atmosphere.	Capacity in cu. ft. free gas per 24 hrs., based on 14.4 lbs. atmospheric pressure.
150	30,800,000
100	20,700,000
75	15,600,000
50	10,500,000
30	6,550,000
20	4,170,000

No Heat Loss in Gas Compression. Contrary to a widespread popular opinion, the compression of natural gas does not decrease its heating value. While a certain amount of gas is used to drive the compressors, this does not in any way affect the heating value of the gas passing through the compressors. The only shrinkage will be the gasoline that condenses in the transmission lines, and the percentage thus removed is so small, considering the large volume of gas handled, as to be negligible. In a recent test this gasoline loss was found to be less than 1/6 of 1 per cent. In view of the preceding facts, the heating value per cubic foot of gas at the end of the transmission lines will be essentially the same as in the gas field.

Two Gas Lines on Side of Mountain in West Va.

Refrigerating Effect of Expanding Natural Gas. When natural gas is allowed to expand from a high to a lower pressure the expansion causes an absorption of heat from and tends to freeze surrounding objects. The principle involved is exactly the same as the expansion of ammonia in artificial ice plants. It is to counteract this freezing tendency that the gas must be heated adjacent to regulators when the pressure is lowered.

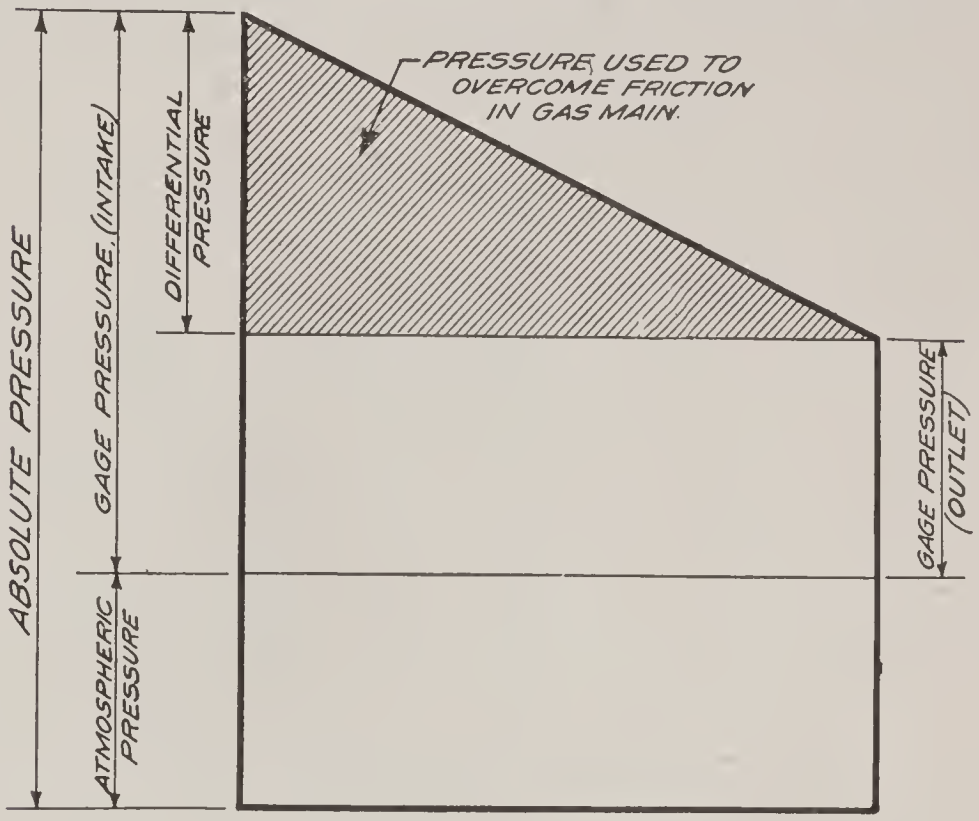
Gas Pressure Terms. These are illustrated in the diagram at the right.

Gage Pressure: This is simply the pressure indicated by a pressure gage.

Barometric Pressure: Atmospheric pressure is measured by a barometer, and is synonymous with barometric pressure. This must be considered in most gas calculations.

Absolute Pressure: This is the sum of the gage pressure and the barometric pressure. Thus, if the gage pressure is 25.3 lbs. and the barometric pressure is 14.7 lbs., the absolute pressure will be 25.3 + 14.7 = 40 lbs.

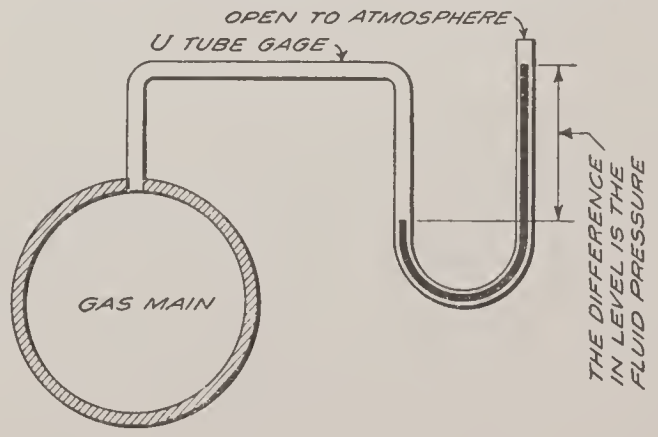
DIAGRAM ILLUSTRATING GAS PRESSURE TERMS



Differential Pressure: This is simply the difference between the pressure at the inlet and outlet of a gas line, as shown in diagramatic form above. Thus if the inlet gage pressure were 15 lbs. and the outlet gage pressure 10 lbs., the differential pressure would be 5 lbs. In gas transmission it is necessary to have a high differential pressure in order to secure enough driving power to force the gas through the main.

Fluid Gages for Gas Pressure Measurement. Fluid gages are also known as manometers, the simplest form of which is the U glass tube shown at the right. When no pressure is applied other than the prevailing atmospheric pressure, the liquid will stand at the same level in both tubes. When the gas main is under pressure above the atmosphere, the liquid in the tube will be lowered. The difference in levels is then the fluid pressure. The choice of fluids is determined by the pressure to be observed, the fluid of greater density being required for higher pressure.

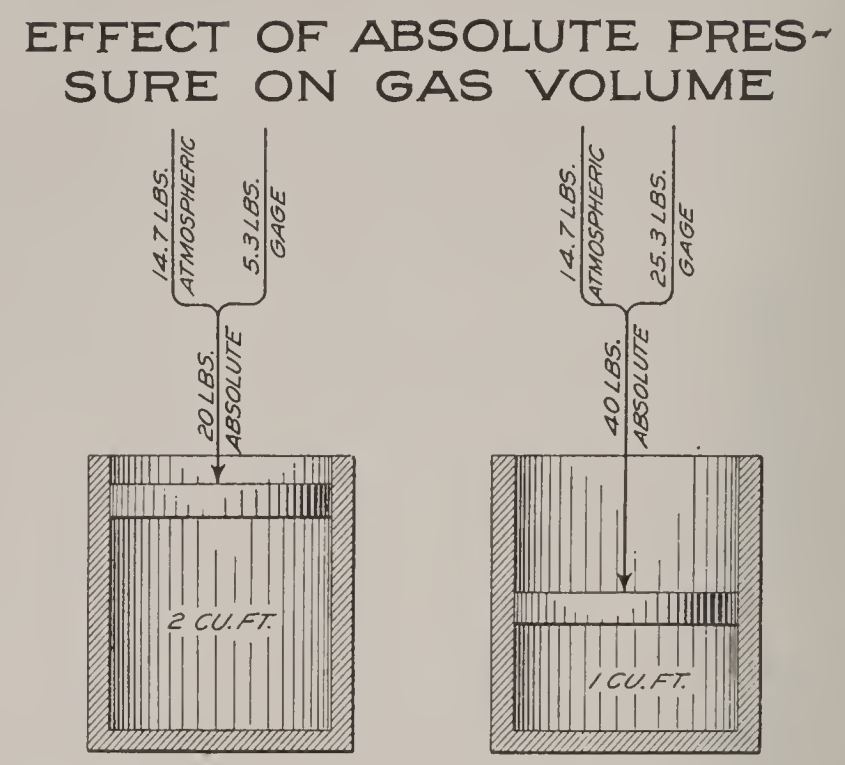
GAS PRESSURE MEASUREMENT BY FLUID GAGE



Effect of Pressure on Gas. For engineering purposes, at a given temperature the volume of gas is inversely proportional to the absolute pressure to which the gas is subjected, as shown at the right. That is, the product of the absolute pressure and the volume of a given amount of gas remains constant.

Variation in volume of 100 cu. ft. (100%) of gas at constant temperature under various pressures.

Pressure per sq. in.	Volume
0 oz.	100.0%
2 "	99.1
4 "	98.3
6 "	97.5
8 "	96.7
12 "	95.1
1 lb.	93.6
5 "	74.6
10 "	59.5
20 "	42.3
50 "	22.7
75 "	16.8
100 "	12.8
150 "	8.9
200 "	6.8
250 "	5.5
300 "	4.6
400 "	3.5



This emphasizes the small difference in volume—or relative heating value—with even several ounces difference of pressure.

Gas Pressure Unit Equivalents.

1 in. of water = .073 in. mercury = .57 oz. per sq. in. = .036 lbs. per sq. in.

1 oz. per sq. in. = 1.73 in. water = .127 in. mercury = .062 lbs. per sq. in.

Relation of Pressure and Pipe Diameter. The diameter of a main to discharge a given quantity of gas at various pressures varies inversely as the fifth root of the pressure.

				Typical relative cost of black pipe per 100 ft. exclusive of labor.
16 lbs.	requires	2-in.	main	$ 9.00
9 "	"	2.5-in.	"	14.00
4 "	"	3-in.	"	18.00
4 oz.	"	5-in.	"	36.00

Effect of Pressure on Gas Line Flow. The quantity of gas carried by a gas line varies directly as the square root of the differential pressure. Hence, to double the flow in any line it is necessary to quadruple the pressure. This has a vital effect on the cost of compressing gas in order to transmit it long distances, thus relatively:

400	lbs.	discharges	5000	cu. ft.
100	"	"	2500	" "
16	"	"	1000	" "
4	"	"	500	" "
1/4 lb. (4 oz.)		"	125	" "

Gas Leakage Laws.

1. The amount of gas leaking from a pipe system is entirely independent of the volume of gas passing through the pipes. In other words, under the same conditions of pressure the amount of gas lost will be the same during the period of low gas consumption as during the period of high gas consumption.

2. The leakage tendency varies directly as the square root of the pressure. Thus, the leakage tendency at 100 lbs. and 4 lbs. will be as 5 is to 1.

Sea Level Rating. The effect of altitude on gas apparatus capacity is shown in the following:

Elevation above Sea level in feet	Barometric pressure in inches of mercury	Relative capacity in per cent
0	29.92	100.
500	29.35	98.9
1000	28.82	96.3
1500	28.30	94.5
2000	27.78	92.5

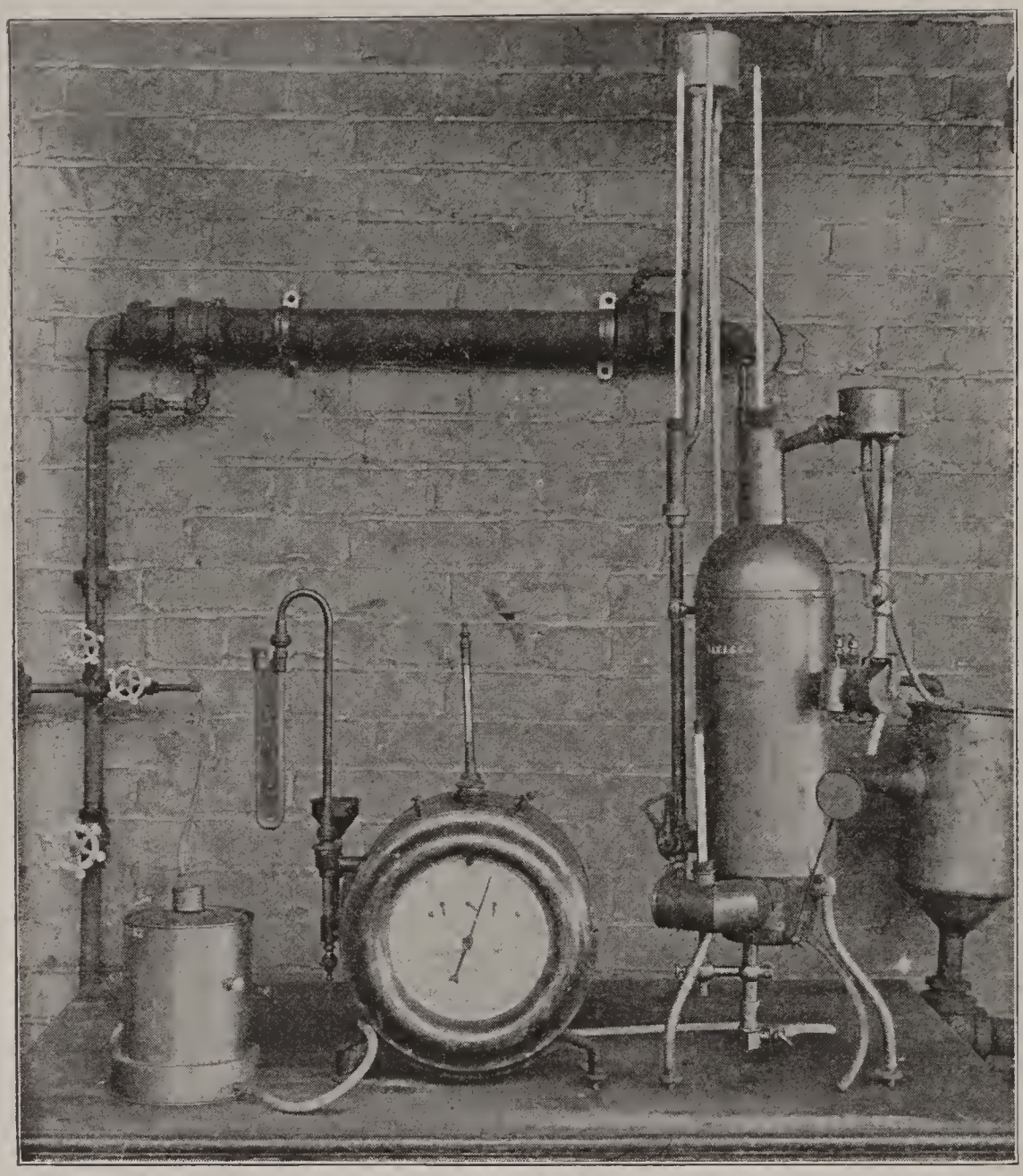
Thus, a gas engine rated at 100 H. P. at sea level will produce only 92.5 H. P. at 2000 ft. elevation.

Absolute Temperature. The real starting point in gas activity is not the ordinary zero point, but absolute zero, which is 460 degrees below zero, or 492 degrees below freezing on the Fahrenheit scale. Absolute temperature is therefore the temperature reckoned from absolute zero, and is simply the sum of 460 degrees and the observed temperature.

Effect of Temperature on Gas. The volume of any gas free to expand, or the pressure of any confined gas increases or decreases just as its absolute temperature increases or decreases. Hence, at a given constant pressure the volume of a given amount of gas is directly proportional to its absolute temperature.

The volume or pressure will therefore vary approximately 1 per cent for each 5 degrees Fah. change. The object of the cooling basin shown adjacent to the compressing station on the outside cover of this pamphlet is to lower the temperature of the gas so as to decrease its volume and thereby increase the carrying capacity of the transmission line. In a typical case the temperature is lowered 120 degrees by the cooling water, thus causing a contraction in volume of about 24 per cent.

Standard Conditions. Since the volume of natural gas varies with the temperature and pressure, in order to secure comparable results in gas calculations and the establishment of standards, a standard condition is necessary. This is usually taken at 32° Fah. and a pressure of 29.9 inches of mercury, although in many cases 60° Fah. is used.



Calorimeter for Determining Heating Value of Gas

Dilution of Gas With Air. The following expert opinions show that the widespread popular opinion that natural gas is diluted with air is without foundation. It is an easy matter to test for this at any time by simply determining the heating value of the gas in a calorimeter, as shown above. The presence of air in the gas would always be indicated by the calorimeter showing a heating value below the normal.

> "The author has made many independent determinations of the oxygen content of gas drawn from the pipe lines, but has never found a sufficient amount to indicate that air has been introduced. The matter is mentioned here because expression is often given to the belief that air is surreptitiously forced into the mains with the gas, but no hesitation is felt by the writer in stating that this is never done." (1)

> "This office has had the gas analyzed by the City Chemist from time to time; and has also checked over reports from the Chemist at the University of Kansas, and cannot find any air or other adulterations in the same." (2)

(1) Prof. P. F. Walker, Engineering Bulletin No. 2, published by the Kansas Public Utilities Commission, p. 5.

(2) Report of Robert W. Goodnow, City Gas Inspector, Kansas City, Mo., p. 13.

"We are using natural gas and have examined the gas twice a month for about three years, and have never been able to detect air in the natural gas at Pittsburg." (3)

"We have found that the popular idea that the Company deliberately dilutes with air the gas in the gas fields is not based on facts." (4)

Heat Unit. The heat required to raise one pound of water one degree Fah. is called a British thermal unit, and abbreviated B. t. u.

Heating Value. This is the number of heat units that are evolved by the combustion of a unit weight or volume of fuel. The terms "calorific value," "calorific power," "heating power," "thermal value" and "heat of combustion" are frequently applied to the same phenomenon.

The heating value of gas may be determined experimentally by means of an apparatus known as a calorimeter, which is shown on p. 24.

Candle Power Hour. When illuminating gas—which was the first illuminating utility service—was introduced, it was placed in direct competition with candles. In order that a comparison might be made between the relative worth of gas and candles, the illuminating strength of the then new gas was measured in terms of the illumination produced by a candle. Thus, a 16-candle power gas produced 16 times as much light as its competitor, the candle.

The term "candle power hour" means the illumination produced by one candle power for the period of one hour. The number of candle power hours available from one dollar's worth of various illuminating services and commodities is shown in the third column from the right on p. 9. This shows at once that the worth of 50-cent natural gas is much more than any other illuminating medium, even including the coal oil lamp.

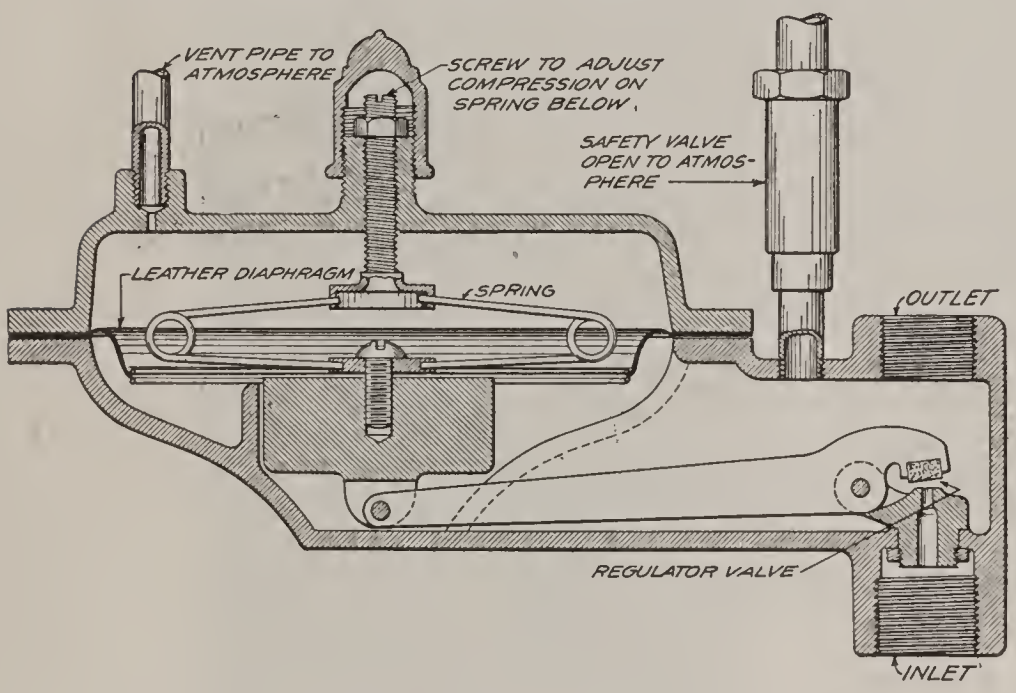
(3) Geo. A. Burrell, U. S. Bureau of Mines, p. 210, Vol. 4, Proceedings of the Natural Gas Association of America.

(4) Report on Natural Gas Service Rendered the City of Columbus, Ohio. By Consulting Engineers E. A. Hitchcock and Samuel S. Wyer, p. 28.

Gas Line in Trench

Gas Regulator. This is a device to step-down the pressure from a high pressure line to a line of lower pressure and a typical regulator is shown on this page. Atmospheric pressure bears down on the top side of the diaphragm by virtue of the connection through the vent pipe. The exact "low" pressure to be maintained on the outlet side may be varied by changing the compression on the springs above the diaphragm by means of the adjusting screw, as shown. The high pressure gas going in expands and acts on the lower side of the diaphragm, pushing up the diaphragm against the atmosphere and action of the springs. When the diaphragm moves up so that the pressure underneath it equals the low pressure for which it is set it will close the inlet valve until there is a very slight reduction of pressure on the outlet side, when the atmospheric pressure will force the diaphragm down and allow more high pressure gas to enter.

GAS PRESSURE REGULATOR



The safety valve is to protect the low pressure fixtures in case the regulator should stick open. An ordinary mercury seal is frequently used for this.

In distributing natural gas it is sometimes desirable to take advantage of the laws discussed on page 22, and permit the use of high or medium pressure to get the gas out to the consumer's premises and at the same time maintain a uniform and adequate low pressure at the consumer's fixtures by means of a gas regulator. This is an engineering matter pure and simple, and no hard and fast rules can be given as to when regulators ought or ought not be installed on the consumer's premises.

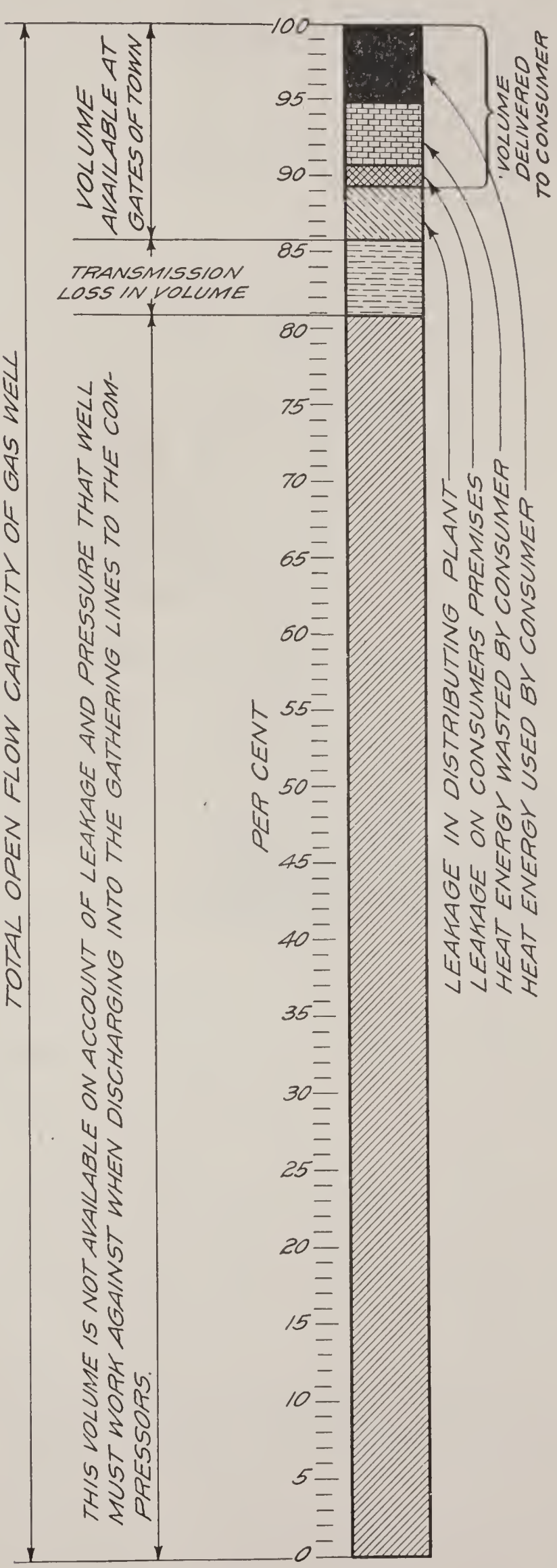
Rock Pressure of Natural Gas. This is merely the pressure resulting from nature's compression of the gas in the underground reservoirs, and it is this pressure that forces the gas out when the reservoirs are tapped by drilled holes. As the reservoirs are emptied, the rock pressure decreases, thus lowering the delivering capacity of the wells. The following, based on actual records, show the average rock pressures in pounds, per square inch, for the respective gas fields, and years:

Ashland, Ohio	1910,	1050	lbs.	1913,	300 lbs.
Homer, Ohio	1902,	750	"	1912,	175 "
Sugar Grove, Ohio	1895,	800	"	1912,	100 "
Independence, Kas	1905,	340	"	1912,	75 "
Hogshooter, Okla	1910,	550	"	1912,	100 "

PER CENT OPEN FLOW GAS WELL CAPACITY AVAILABLE FOR USE

Open Flow Capacities of Gas Wells. Unfortunately, the well capacities that are generally reported by the newspapers and represented to gullible investors are the open flow capacities when the wells are discharging freely into the atmosphere. These open flow capacities are very much larger than the actual delivering capacities under routine operating conditions, as shown at the right. The data shown in this illustration were obtained by first determining the open flow capacities of representative wells and then passing the gas from these wells through meters, noting the amount that was actually delivered to the gas compressors.

It is also important to note that even after the gas reaches the consumer's premises much is lost, due to leakage and ineffective methods for utilizing the gas.



Magnitude of Natural Gas Business. The following facts, compiled by the U. S. Geological Survey, will serve to give the true perspective of the natural gas business for the year 1911:

Industrial gas consumption	337,000,000	"M" cu. ft.
Domestic " "	171,000,000	" " "
Total	508,000,000	" " "
Industrial gas consumers	14,000	
Domestic " "	1,500,000	
Total	1,514,000	
Number producing wells drilled	3,226	
" dry holes	1,058	
Total wells drilled	4,284	
Number of wells abandoned	2,103	
" of wells in use end of 1911	28,428	
" of acres owned or under lease		11,132,000
" of acres owned or under lease per producing well		390

Conservation of Natural Gas. The history of the natural gas industry of the United States is an appalling record of incredible waste. Much more gas is wasted today than is used. This is due largely to the fact that the selling prices for natural gas have been so low as not to warrant the expenditures necessary for conserving the supply.

"The only wise way for cities to do is to allow gas companies sufficient price so they can afford to prospect for, buy and hold gas territory for the present and future use. Show the profit, and conservation will take care of itself." "A great many cities have tried to lower the gas rates when, as a matter of fact, they should have been increased to insure the highest efficiency and to prolong the service for years. Whatever may be the opinion of the general public in the matter, it is a fact that the rates charged by public utility corporations for natural gas in this country are, in most cases, too low rather than too high, and that the most efficient regulation can be successfully accomplished only by raising rates to such a point that consumers will not waste gas." (1)

(1) Technical Paper 38, U. S. Bureau of Mines. Waste in the Production and Utilization of Natural Gas, and Means for Their Prevention. By Ralph Arnold and Frederick G. Clapp.

Regeneration. While no one knows exactly how natural gas is formed, yet enough facts are known about it to indicate that nature's process is a slow one and that, therefore, even if there should be any regeneration in the present depleted fields, the rate of regeneration will be so slow as to make new gas pools formed of no interest or economic value for many generations.

Quality and Quantity of Natural Gas Fixed by Nature. The quantity is always uncertain and the quality may vary through a small range for the different fields. However, it is not commercially feasible to attempt to correct variation in quality by any artificial means and furnish a gas that is uniform, as may be done in an artificial gas plant, for the simple reason that the cost of doing this would be much more than the additional worth of the service under such conditions.

Salt Water in Gas Wells. Salt water is found in most natural gas formations and is always troublesome. Large quantities of gas are wasted annually in freeing the wells from salt water, which is done by blowing the water and gas into the air, as shown at the right. As the wells become weaker, periodical water pumping must be resorted to to keep the wells in working shape.

Gas Well Blowing Salt Water.

Regulation of Natural Gas Companies. The inherent right of the government to regulate all public service corporations, ordinarily called utilities—of which natural gas is a typical example—has been clearly established by the United States Supreme Court and other federal courts, and is now regarded as a basic principle of American law. (1)

> "When one devotes his property to a use in which the public has an interest, he, in effect, grants to the public an interest in that use, and must submit to be controlled by the public for the common good, to the extent of the interest he has thus created. He may withdraw his grant by discontinuing the use; but, so long as he maintains the use, he must submit to the control. (2)

(1) For a complete discussion of the Governmental power to regulate, Protection of utilities from adverse regulation, Requirements of regulation, and Relief from oppressive regulation, see Wyer's Regulation, Valuation and Depreciation of Public Utilities.

(2) Vol. 94, U. S. Supreme Court Reports, pp. 126, 130, 165, Munn v. Illinois.

However, such powers can be legally exercised only within clearly defined limits, as discussed in the following sections.

United States Supreme Court View of Regulation Problem.

"Regulation of Utilities which perform their duties under conditions of necessary monopoly will occur with greater and greater frequency as time goes on. It is a delicate and dangerous function and ought to be exercised with a keen sense of justice on the part of the regulating body, met by frank disclosure on the part of the Utility to be regulated." (1)

"The courts ought not bear the whole burden of saving property from confiscation, though they will not be found wanting when the proof is clear. The legislatures and subordinate bodies, to whom the legislative power has been delegated, ought to do their part." (1)

"Our social system rests largely upon the sanctity of private property, and that state or community which seeks to invade it will soon discover the error in the disaster which follows. The slight gain to the consumer, which he would gain from a reduction in the rates charged by Utilities, is as nothing compared with his share in the ruin which would be brought about by denying to private property its just reward, thus unsettling values and destroying confidence." (1)

What is Regulation?

"Utility regulation is the branch of legal science that defines the rights and duties existing between the Public and Public Utility. The function of regulation is to establish and enforce the duties, maintain and protect the rights of both, and prevent either from tyrannizing over, or otherwise injuring, the other. Thus, regulation preserves private property interests by reconciling them with public right." (2)

"Regulation is not a cudgel to be used by either interest over the other, but a code to be observed by both. To be permanently effective, it must be just and equitable. The State's duty to protect is just as clear as its duty to control. Furthermore, you cannot found and maintain a business unless you have a law to protect it." (2)

What Regulation is Not.

"The popular but erroneous conception of regulation is that it is an arbitrary governmental power to make a Utility yield to legislative control or caprice. However, this is far

(1) Vol. 212 U. S. Supreme Court Reports, p. 18. Knoxville v. Water Co.

(2) Wyer's Regulation, Valuation and Depreciation of Public Utilities, pp. 9 and 10.

from the truth. Such governmental power is not regulation, but tyranny, and would result in anarchy." (1)

"When we consider the nature and the theory of our institutions of government, the principles upon which they are supposed to rest, and review the history of their development, we are constrained to conclude that they do not mean to leave room for the play and action of purely personal and arbitrary powers." (2)

Regulation Must Be Based on Predetermined Facts. The arbitrary fixing of a rate without a comprehensive investigation of all the facts, and the unbiased hearing of evidence regarding those facts, is like a court rendering a decision without giving the two interested parties an opportunity to argue their respective sides of the case.

"It is not a matter of guesswork or arbitrarily fixing of rates. When the constitution provides for the fixing of rates for compensation it means reasonable rates and just compensation." (3)

"The very use of the term 'regulation' implies that investigation shall be made; that an opportunity to present the facts shall be furnished; that, when the facts are established, they shall, by the regulating power, be given due consideration; and that such action as shall be taken in view of these facts thus ascertained, shall be just and reasonable." (4)

Regulation Must Be Based on Just Compensation. The regulating power of the State is not one "to destroy, or a power to compel the doing of service without reward." (5)

"If the company is deprived of the power of charging reasonable rates for the use of its property, it is deprived of the lawful use of its property. In every constitution is the guarantee against the taking of private property for public purposes without just compensation." (6)

(1) Wyer's Regulation, Valuation and Depreciation of Public Utilities, pp. 9 and 10.

(2) Vol. 176 U. S. Supreme Court Reports, p. 172. C. M. & S. P. v. Tompkins.

(3) Vol. 174 U. S. Supreme Court Reports, p. 750. San Diego L. Co. v. National City.

(4) Vol. 72 Federal Reporter, p. 955. New Memphis G. L. Co. v. Memphis.

(5) Vol. 143 U. S. Supreme Court Reports, p. 547. Budd v. New York.

(6) Vol. 169 U. S. Supreme Court Reports, p. 523. Smyth v. Ames.

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Regulation Must Not Be Arbitrary.

"The legislature may not, under the guise of protecting the public interests, arbitrarily interfere with private business or impose unusual or unnecessary restrictions upon lawful occupations." (1)

Regulation Must Not Confiscate.

"From what has been said, it is not to be inferred that this power of limitation or regulation is itself without limit. This power to regulate is not a power to destroy, and limitation is not the equivalent of confiscation." (2)

Regulation Must Be Just.

"No legislature or commission, acting under the authority of the legislature, can arbitrarily and without regard to justice and right, establish a tariff of rates which is so unreasonable as to practically destroy the value of property of persons engaged in business." (3)

What an Equitable Natural Gas Rate Must Provide for.

I. Recognition of worth of service to consumer.

II. Recognition of consumer's service characteristics

III. Recognition of true investment in plant. This must include physical and intangible property and cost of developing business.

IV. Payment of all operating expenses.

V. Return on investment that will include,

1st. Legal rate of interest;

2nd. Profit commensurate with the hazard involved;

3rd. Provision to keep the investment at all times intact.

VI. Each consumer paying for service he receives. This requires:

1st. The exaction of adequate security for the payment of bills;

2nd. Exaction of a minimum charge because, "the minimum rates are intended to cover the fixed expenses for those who use so little service that the cost of carrying them would not otherwise be met." (4)

(1) Vol. 152 U. S. Supreme Court Reports, p. 137. Lawton v. Steele.

(2) Vol. 116 U. S. Supreme Court Reports, p. 331. R. R. Commission Cases.

(3) Vol. 134 U. S. Supreme Court Reports, p. 459. C. M. & St. P. v. Minnesota.

(4) Vol. 4 Wisconsin Railroad Commission, p. 89.

Gas Well

Gas Well Drilling Rig

Typical Log of Gas Well showing Geological Formations

Sand & Gravel

Sand & Slate

Slate

Berea Grit

Slate

Lime

Slate

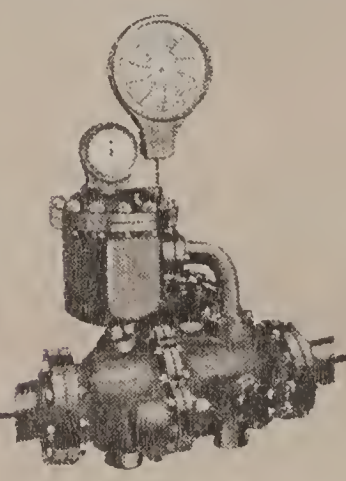
Shell

Slate

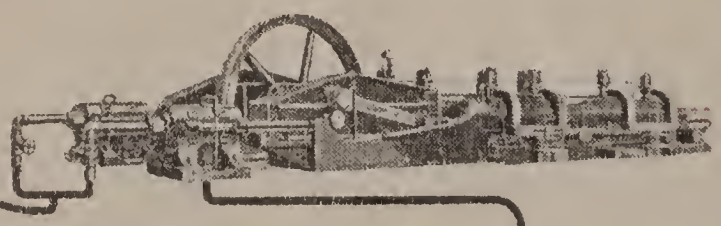
Clinton Gas Sand

300 LBS.±

Gas Measuring Station in Field



50 LBS.



Gas Compressing Station

300 LBS.

Gas Cooling Basin